BS EN 60794-4:2003

Optical fibre cables —

Part 4: Sectional specification — Aerial optical cables along electrical power lines

The European Standard EN 60794-4:2003 has the status of a British Standard

ICS 33.180.10

British Standards

National foreword

This British Standard is the official English language version of EN 60794-4:2003. It is identical with IEC 60794-4:2003. It supersedes BS EN 187200:2001 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/86, Fibre optics, to Subcommittee GEL/86/1, Optical fibres and cables, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

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Optical fibre cables Part 4: Sectional specification – Aerial optical cables along electrical power lines (IEC 60794-4:2003)

Câbles à fibres optiques
Partie 4: Spécification intermédiaire -
Câbles optiques aériens le long des lignes électriques de puissance
(CEI 60794-4:2003)

Lichtwellenleiterkabel
Teil 4: Rahmenspezifikation -
Lichtwellenleiter-Luftkabel auf Starkstrom-Freileitungen
(IEC 60794-4:2003)

This European Standard was approved by CENELEC on 2003-11-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
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Foreword

The text of document 86A/851/FDIS, future edition 1 of IEC 60794-4, prepared by SC 86A, Fibres and cables, of IEC TC 86, Fibre optics, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60794-4 on 2003-11-01.

This European Standard supersedes EN 187200:2001.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2004-08-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2006-11-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annex ZA is normative and annex A is informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60794-4:2003 was approved by CENELEC as a European Standard without any modification.

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OPTICAL FIBRE CABLES –

Part 4: Sectional specification – Aerial optical cables along electrical power lines

1 Scope

This part of IEC 60794 specifies the electrical, mechanical and optical requirements and test methods for aerial optical cables including OPGW (optical ground wire), OPPC (optical phase conductor), MASS (metallic aerial self-supported cable), ADSS (all-dielectric self-supporting cable) and OPAC (optical attached cable).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

They complete the normative references already listed in the generic specification (IEC 60794-1-1, Clause 2, and IEC 60794-1-2, Clause 2) and in the sectional specification (IEC 60794-3, Clause 2).

IEC 60104:1987, *Aluminium-magnesium-silicon alloy wire for overhead line conductors*

IEC 60304:1982, *Standard colours for insulation for low-frequency cables and wires*

IEC 60708-1:1981, *Low-frequency cables with polyolefin insulation and moisture barrier polyolefin sheath – Part 1: General design details and requirements*

IEC 60794-3:2001, *Optical fibre cables – Part 3: Sectional specification – Outdoor cables*

IEC 60811-4-2:1990, *Common test methods for insulating and sheathing materials of electric cables – Part 4: Methods specific to polyethylene and polypropylene compounds – Section Two: Elongation at break after pre-conditioning – Wrapping test after pre-conditioning – Wrapping test after thermal ageing in air – Measurement of mass increase – Long-term stability test (Appendix A) – Test method for copper-catalysed oxidative degradation (Appendix B)*

IEC 60811-5-1:1990, *Common test methods for insulating and sheathing materials of electric cables – Part 5: Methods specific to filling compounds – Section one: Drop point – Separation of oil – Lower temperature brittleness – Total acid number – Absence of corrosive components – Permittivity at 23 °C – DC resistivity at 23 °C and 100 °C*

IEC 60888:1987, *Zinc-coated steel wires for stranded conductors*

IEC 60889:1987, *Hard-drawn aluminium wire for overhead line conductors*

IEC 61089:1991, *Round wire concentric lay overhead electrical stranded conductors*

IEC 61232:1993, *Aluminium-clad steel wires for electrical purposes*

IEC 61394:1997, *Overhead lines – Characteristics of greases for aluminium, aluminium alloy and steel bare conductors*

IEC 61395:1998, *Overhead electrical conductors – Creep test procedures for stranded conductors*

3 Definitions and abbreviations of cables

3.1 Definitions

For the purposes of this document, the following definitions and abbreviations of cables apply.

3.1.1
MAT
maximum allowable tension
maximum tensile load that may be applied to the cable without detriment to the tensile performance requirement (optical performance, fibre strain)

3.1.2
RTS
rated tensile strength
summation of the product of nominal cross-sectional area, minimum tensile strength and stranding factor for each load bearing material in the cable construction (refer to Annex A in the case of OPGW)

3.1.3
strain margin
amount of strain the OCEPL can sustain without strain on the fibres due to the OCEPL's elongation

3.2 Abbreviations of cables

ADSS all-dielectric self-supporting cable

MASS metallic aerial self-supported cable which is not designed to have ground or phase capability

OCEPL optical cable to be used along electrical power lines

OPAC optical attached cable consisting of the following three attachment methods:

- **wrapped:** all-dielectric (wrap). Using special machinery, a lightweight flexible non-metallic cable can be wrapped helically around either the earth wire or the phase conductor.
- **lashed:** non-metallic cables that are installed longitudinally alongside the earth wire, the phase conductor or on a separate catenary (on a pole route) and are held in position with a binder or adhesive cord.

- **preform attached:** similar to the lashed cables except that the method of attachment involves the use of special preformed spiral attachment clips.

OPGW optical ground wire. An OPGW has the dual performance functions of a conventional ground wire with telecommunication capabilities.

OPPC optical phase conductor. An OPPC has the dual performance functions of a phase conductor with telecommunication capabilities.

4 Optical fibre

4.1 General

Single-mode optical fibre which meets the requirements of IEC 60793-2 shall be used. Fibres other than those specified above can be used, if mutually agreed between the customer and the supplier.

4.2 Attenuation

4.2.1 Attenuation coefficient

The typical maximum attenuation coefficient of a cable at 1 310 nm is 0,45 dB/km and/or at 1 550 nm it is 0,30 dB/km. Particular values shall be agreed between the customer and the supplier.

The attenuation coefficient shall be measured in accordance with IEC 60793-1-40.

4.2.2 Attenuation uniformity

4.2.2.1 Attenuation discontinuities

The local attenuation shall not have point discontinuities in excess of 0,10 dB.

The test method best suited to provide the functional requirements is in accordance with IEC 60793-1-40.

4.2.2.2 Attenuation linearity

The functional requirements are under consideration.

4.3 Cut-off wavelength of cabled fibre

The cabled fibre cut-off wavelength λcc shall be less than the operational wavelength.

4.4 Fibre colouring

If the primary coated fibres are coloured for identification, the coloured coating shall be readily identifiable throughout the lifetime of the cable and shall be a reasonable match to IEC 60304. If required, the colouring shall permit sufficient light to be transmitted through the primary coating to allow local light injection and detection. Alternatively, the colour may be removable.

4.5 Polarization mode dispersion (PMD)

Refer to 5.5 of IEC 60794-3.

5 Cable element

Generally, optical cables comprise several elements or individual constituents, depending on the cable design, which take into account the cable application, operating environment and manufacturing processes, and the need to protect the fibre during handling and cabling.

The material(s) used for a cable element shall be selected to be compatible with the other elements in contact with it. An appropriate compatibility test method shall be defined in the family or product specification.

Optical elements (cable elements containing optical fibres) and each fibre within a cable element shall be uniquely identified, for example, by colours, by a positional scheme, by markings or as specified in the product specification.

Different types of optical elements are described below.

5.1 Slotted core

The slotted core is either a metallic (for example, aluminium alloy) or non-metallic (for example, polyethylene or polypropylene) material with a defined number of slots, with longitudinal, helical or SZ configuration along the core. One or more primary coated fibres or optical element is located in each slot which shall be filled, if necessary, with a suitable water blocking system.

If metallic, it shall be electrically bonded with the other metallic elements of the cable. If non-metallic, the slotted core usually contains a central element which shall be non-metallic. In this case, there shall be adequate adhesion between the central element and the extruded core in order to obtain the required temperature stability and tensile behaviour for the slotted core element.

The profile of the slot shall be uniform and shall ensure the optical and mechanical performance required for the optical cable.

5.2 Plastic tube

One or more primary coated fibres or optical elements are packaged, loosely or not, in a tube construction which shall be filled, if necessary, with a suitable water-blocking system. The plastic tube may be reinforced with a composite wall.

If required, the suitability of the tube shall be determined by an evaluation of its kink resistance in accordance with IEC 60794-1-2, Method G7.

The filling compound in the tube shall comply with IEC 60794-1-2, Method E14 (compound flow (drip)) or Method E15 (bleeding and evaporation).

5.3 Ribbon

Optical fibre ribbons are optical fibres assembled in accordance with IEC 60794-3.

5.4 Metallic tube

5.4.1 Metallic tube on the optical core

A metallic tube (for example, aluminium tube) may be applied over the optical core (for example, aluminium spacer or stranded tube).

5.4.2 Fibres directly located in a metallic tube

One or more primary coated and coloured fibres are packaged in a metallic hermetically sealed tube, which shall be filled with a suitable compound if necessary to avoid water penetration.

The inside surface of the tube should be smooth without any defects.

6 Optical fibre cable construction

6.1 General

The cable shall be designed and manufactured for a predicted operating lifetime depending on the type of cable. The attenuation of the installed cable at the operation wavelength(s) shall not exceed values agreed between the customer and the supplier.

There shall be no fibre splice in a delivery length unless otherwise agreed by the customer and the supplier.

It shall be possible to identify each individual fibre throughout the length of the cable.

If mutually agreed between customer and supplier to avoid excess fibre strain induced by the environmental conditions, such as wind or ice loading, the cable construction and particularly the strength members shall be selected to avoid any long-term detrimental effects on fibres up to the specified MAT.

The optical fibre unit shall house the optical fibres and protect them from damage due to environmental or mechanical forces such as longitudinal compression, crushing, bending, twisting, tensile stress, long- and short-term heat effects.

The aerial cable types can be divided into the following groups:

– optical ground wire or optical phase conductor (OPGW or OPPC);
– all-dielectric self-supporting cable (ADSS);
– optical attached cables (OPAC);
– metallic aerial self-supported cables (MASS).

These aerial cables have different constructions, environmental and electrical operating conditions for use on high-voltage lines.

6.2 Lay-up of the cable elements

Optical unit elements as described in Clause 5 may be laid up as follows:

a) single optical unit in the cable centre, which may contain one or more optical elements;
b) a number of homogeneous optical elements using helical or SZ stranding configurations (ribbon elements may be laid up by stacking two or more elements);
c) a number of hybrid configurations in slotted core such as ribbon or plastic tube, which may contain one or more optical elements.

For OPGW, if required, insulated copper conductors in single, pair or quad construction may be laid up with the optical elements.

6.3 Cable core filling

If specified, the element(s) and in addition the cable core shall be continuously filled with water-blocking material. Alternatively, water blocks may be applied at regular intervals. The material shall be easily removed without the use of materials considered to be hazardous or dangerous.

The blocking material used shall be compatible with the other relevant cable elements. Where a filling compound is used, its suitability shall be demonstrated by the use of the following test methods:

a) The amount of oil separation from the filling compound shall meet the requirements of Clause 5 of IEC 60811-5-1; alternatively, the filling compound shall be tested in accordance with IEC 60794-1-2, Method E15.
b) For cables containing metallic elements, the filling compound shall be tested for the presence of corrosive compounds in accordance with IEC 60811-5-1, Clause 8.
c) The filling compound shall not be liquid at temperatures lower than a specified value. The determination of the drop point shall be in accordance with IEC 60811-5-1, Clause 4.
d) Increase in weight shall be tested as specified in IEC 60811-4-2, Clause 11. The increase in weight shall not exceed the value specified for the particular material.
e) Where the blocking material is water swellable, suitability tests are under consideration.

6.4 Strength members

The type of materials used as strength members shall fulfil the mechanical and thermal requirements of the overhead lines.

6.4.1 OPGW, OPPC and MASS

The stranded wires used for armouring may be round according to IEC 61089 or other cross-sectional shapes, i.e. trapezoidal or z-form and can be of the following materials:

– aluminium alloy IEC 60104;
– galvanized steel IEC 60888;
– aluminium IEC 60889;
– aluminium-clad steel IEC 61232.

These specifications give requirements on wire before stranding.

Unless other requirements are mutually agreed between the customer and the supplier, after stranding, the wires shall meet the requirements of IEC 61089.

Materials other than those specified can be used if mutually agreed between the customer and the supplier.

In order to reduce the risk of corrosion, it may be necessary for the armouring to be greased. See 9.15.

6.4.2 ADSS and OPAC

The strength member elements shall consist of aramid yarns, glass-reinforced materials or equivalent dielectric strength members.

6.5 Inner sheath

A cable inner sheath may be applied by agreement between the customer and the supplier.

6.6 Outer sheath

If the aerial cable has an outer sheath, this shall be made of UV-stabilized weather-resistant material in accordance with IEC 60708-1, Clause 22, unless otherwise agreed between the customer and the supplier. In the case of ADSS and OPAC, in certain conditions it shall be necessary to consider the use of a tracking-resistant sheath.

6.7 Sheath marking

For non-metallic aerial cable, the sheath may be marked by a method agreed between the customer and the supplier.

If there is a risk due to high-voltage tracking effects, then sheath marking may be omitted.

7 Main requirements for installation and operating conditions

7.1 General

Installation and operating conditions shall be agreed upon between the customer and the supplier. Operating conditions are particularly important for aerial cables.

7.2 Characterization of optical units for splicing purpose

For characterization of the different types of cable elements for splicing purposes, refer to IEC 60794-3.

8 Design characteristics

Table 1 is a summary of important OCEPL characteristics which may be of relevance to both the customer and the supplier. Other characteristics may be mutually agreed upon by both the customer and the supplier.

Table 1 – Design characteristics

Refer-ence	Design characteristics	OPGW	OPPC	MASS	ADSS	OPAC
(1)	Number and type of fibres	X	X	X	X	X
(2)	Detailed description of the cable design	X	X	X	X	X
(3)	Overall diameter (mm)	X	X	X	X	X
(4)	Calculated cross-sectional area concerning calculation of RTS (mm^2) (μm^2)	X	X	X	X	-
(5)	Calculated mass (kg/km)	X	X	X	X	X
(6)	RTS – Rated tensile strength (kN)	X	X	X	X	X
(7)	Modulus of elasticity (N/mm^2)	X	X	X	X	X
(8)	Coefficient of thermal expansion (K^{-1})	X	X	X	X	X
(9)	DC resistance (Ω/km)	X	X	-	-	-
(10)	Fault-current capacity I^2t ($kA^2 \times s$)	X	X	-	-	[a]
(11)	MAT – Maximum allowable tension (kN)	X	X	X	X	X
(12)	Allowable temperature range for storage, installation and operation (°C)	X	X	X	X	X
(13)	Strain margin (according to IEC 60794-1-2) (%)	X	X	X	X	X
(14)	Lay direction of outer layer	X	X	X	-	-
(15)	Tracking resistant sheath (if applicable)	-	-	-	X	X

[a] Maximum operating temperature of the cable under short-circuit current shall be specified by the supplier.

9 Optical fibre cable tests

The parameters specified in this part of IEC 60794 may be affected by measurement uncertainty arising either from measurement errors or calibration errors due to the lack of suitable standards. Acceptance criteria shall be interpreted with respect to this consideration. The total uncertainty of measurement for this standard shall be less than, or equal to, 0,05 dB for attenuation.

The expression of no change in attenuation means that any change in measurement value, either positive or negative, within the uncertainty of measurement shall be ignored.

The number of fibres tested shall be representative of the cable design and shall be agreed between the customer and the supplier.

The tests applicable for aerial cables are listed below. The minimum acceptance criteria for the different types of cables are given in the relevant family specifications.

9.1 Classification of tests

9.1.1 Type tests

Tests required to be made before supplying a type of cable covered by this part of IEC 60794 on a general commercial basis in order to demonstrate satisfactory performance characteristics to meet the intended application. These tests shall be carried out on a cable length which meets the requirements of the relevant routine tests. These tests are of such a nature that, after they have been made, they need not be repeated unless significant changes are made in the cable material, design or type of manufacturing process which might change the performance characteristics.

The tests to be repeated shall be agreed between the customer and the supplier.

9.1.2 Sample tests

Tests are made on samples of completed cable or components taken from a completed cable adequate to verify that the finished product meets the design specifications. Scope and incidence of sample tests, if required, shall be agreed between the customer and the supplier.

9.1.3 Routine tests

Tests are made on all production cable lengths to demonstrate their integrity.

9.2 Tensile performance

The cable shall be tested in accordance with IEC 60794-1-2, Method E1.

If required by the product specification, the cable shall be terminated with end fittings relevant to the type of cable considered.

In addition to the test detailed in 9.2, OPAC cables should undergo an additional tensile test having been attached to a messenger cable at the defined installation tension, which is agreed between the customer and the supplier. This test is to ensure that lengthening and retraction of the messenger wire in service will not cause the OPAC to festoon.

9.3 Stress-strain test on metallic cables

Stress-strain tests shall be performed to determine the behaviour of the cable under load conditions and shall be in accordance with IEC 61089, Annex B. Sample length shall be in accordance with IEC 61089 (other sample lengths may be used if mutually agreed between the customer and the supplier).

End fittings such as the helically preformed fittings, cone type, compression, epoxy type, bolted or solder type relevant to the cable type considered shall be used. During the test there shall be no visual damage to the cable strands. All stress and strain values obtained during the test and agreed upon by the supplier and the customer shall be recorded.

If required, the test of 9.2 may be carried out simultaneously with this test.

The Young's modulus should be calculated during the second cycle.

When the test for the breaking strength of the OPGW is required, the OPGW shall withstand without fracture of any wire, not less than 95 % of its RTS.

9.4 Installation capability

Compatibility with particular installation conditions may be demonstrated by selecting from the following tests.

9.4.1 Sheave test

The sheave test shall be performed to verify that the installation of the OPGW, OPPC, MASS and ADSS will not damage or degrade their performance. The cable shall be tested in accordance with the method specified in IEC 60794-1-2, Method E9.

9.4.2 Repeated bending

The cable shall be tested in accordance with the method specified in IEC 60794-1-2, Method E6.

9.4.3 Impact

The cable construction shall be tested in accordance with the method specified in IEC 60794-1-2, Method E4.

9.4.4 Crush

The cable shall be tested in accordance with the method specified in IEC 60794-1-2, Method E3.

9.4.5 Kink

The cable shall be tested in accordance with the method specified in IEC 60794-1-2, Method E10. The minimum diameter shall be agreed between the customer and the supplier.

9.4.6 Torsion

The cable shall be tested in accordance with the method specified in IEC 60794-1-2, Method E7.

NOTE Subclauses 9.4.2 to 9.4.6 are applicable for ADSS and OPAC only.

9.5 Temperature cycling

Unless otherwise specified in the family specification, the cable shall be tested in accordance with the combined test procedure of the method specified in IEC 60794-1-2, Method F1.

9.6 Short circuit

The short-circuit test shall assess the performance of the OPGW, OPPC or OPAC cable and the optical characteristics of the fibres under typical short circuit and has to be tested in accordance with the method specified in IEC 60794-1-2, Method H1.

When agreed between the customer and supplier, the test procedure may be replaced by an adequate theoretical calculation method.

9.7 Lightning test

The cable construction shall be tested in accordance with the method in IEC 60794-1-2, Method H2.

9.8 Ageing

Under consideration.

9.8.1 Fibre coating compatibility

When the fibres are in contact with a filling compound the compatibility of the filling compound with the fibre coating shall be demonstrated by testing after accelerated ageing, either the cabled fibre or the fibre in filling compound for

– stripping force stability in accordance with IEC 60794-1-2, Method E5;
– stability of the colour of the coating for fibre identification (test method is under consideration);

and, if required, for

– dimensional stability;
– coating transmissivity.

Test methods are under consideration.

9.8.2 Finished cable

Under consideration.

9.9 Hydrogen gas

Under consideration.

9.10 Aeolian vibration

The resistance of the cable to aeolian vibration shall be tested in accordance with IEC 60794-1-2, Method E19.

9.11 Creep

If requested, this test is carried out on metallic cables according to IEC 61395.

Under consideration for non-metallic cables.

9.12 Fitting compatibility

The type of fittings shall be approved between the customer and the supplier and their compatibility has to be checked according to the customer's or the supplier's fitting specification.

9.13 Water penetration (for filled cables only)

The cable shall be tested in accordance with IEC 60794-1-2, Method F5B. Other acceptance criteria may be applied in accordance with particular customer requirements.

9.14 Bleeding (for filled cables only)

The bleeding performance of the filling compound of the unit fibre element shall comply with IEC 60794-1-2, Method E15.

9.15 Grease

In order to reduce the risk of corrosion it may be necessary for the strands of OPGW, OPPC and MASS to be coated with grease. The type of grease to be applied shall be in accordance with IEC 61394 or shall be defined between the supplier and the customer.

9.16 Attenuation

The attenuation coefficient shall be measured in accordance with IEC 60793-1-40.

9.17 Tracking and erosion resistance test on ADSS and OPAC

Under consideration.

9.18 Weathering resistance test on ADSS and OPAC

Under consideration.

9.19 Shotgun resistance test on ADSS and OPAC

If requested, this test will be performed according to IEC 60794-1-2, Method E13B.

9.20 Conductor access trolley for OPAC

Under consideration.

10 Quality assurance

Under consideration.

11 Packaging

According to IEC 61089, if applicable, and with the following additional requirements:

a) packaging of the cable shall allow access to one or both ends of the cable in order to perform quality checks;

b) ends of the cable shall be sealed by a suitable method in order to prevent moisture ingress;

c) delivery lengths and tolerance shall be determined in accordance with agreement between the customer and the supplier.

Annex A
(informative)

Recommended methods of calculating rated tensile strength, cross-section of a layer of trapezoidal shaped wires, modulus of elasticity, linear expansion and d.c. resistance

A.1 Calculation of rated tensile strength (RTS)

This calculation should be based on the tensile strength of the armouring and optical unit materials (where applicable) before stranding.

If the OPGW is of type Ax, Ax/Syz or Ax/Ax, the RTS is calculated in accordance with IEC 61089. In cases where the load-bearing elements are homogenous steel or aluminium-clad steel, the RTS is 90 % of the summation of the tensile strength of the individual wires.

A.2 Calculation of the cross-sectional area of a layer of trapezoidal or Z- shaped wires (*A*)

The value should be calculated from the formula:

$$A = (D_o^2 - D_i^2)\,(\pi/4)\,f$$

where

A is the total cross-sectional area of the shaped wire (mm²);

D_o is the outer diameter of the shaped layer (mm)

D_i is the inner diameter of the shaped layer (mm);

f is the space factor.

Typical values:

– aluminium-clad steel/zinc-coated steel wires, f = 0,90
– aluminium, aluminium alloy wires, f = 0,92

A.3 Calculation of the final modulus of elasticity (*E*)

The value should be calculated from the following formula:

$$E = \frac{\sum(E_n A_n)}{\sum A_n}$$

where

E_n is the value of the modulus for each material (N/mm²);

A_n is the cross-sectional area for the corresponding material (mm²).

This formula gives a constant modulus corresponding to a linear stress-strain graph and forms a straight line. This is an approximation of the real modulus of elasticity as achieved from the test given in 9.3.

A.4 Calculation of coefficient of linear expansion (β)

The value should be calculated from the following formula:

$$\beta = \frac{\sum(\beta_n . E_n . A_n)}{\sum(E_n . A_n)}$$

where

E_n is the value of the modulus for each material (N/mm²);

A_n is the cross-sectional area for the corresponding material (mm²);

β_n is the value of the coefficient of linear expansion for each material (K^{-1}).

A.5 Calculation of d.c. resistance (R)

The value should be calculated from the following formula:

$$R = \frac{1}{\sum_n \frac{1}{R_n}}$$

where

R is the linear d.c. resistance of the completed OPGW (Ω/km);

R_n is the linear d.c. resistance of each material (Ω/km);

with

$$R_n = \frac{P}{\sum_i \frac{A_i}{F_i}}$$

where

P is the resistivity of material (Ω × mm²/km);

A_i is the area of a given material in the ith layer (mm²);

F_i is the lay ratio of the ith layer.

NOTE F_i = 1 when the optical element is the central carrier of the OPGW.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60104 [1)]	1987	Aluminium-magnesium-silicon alloy wire for overhead line conductors	-	-
IEC 60304	1982	Standard colours for insulation for low-frequency cables and wires	HD 402 S2	1984
IEC 60708-1	1981	Low-frequency cables with polyolefin insulation and moisture barrier polyolefin sheath Part 1: General design details and requirements	-	-
IEC 60794-3	2001	Optical fibres cables Part 3: Sectional specification - Outdoor cables	EN 60794-3	2002
IEC 60811-4-2 (mod)	1990	Insulating and sheathing materials of electric and optical fibre cables - Common test methods Part 4: Methods specific to polyethylene and polypropylene compounds – Section 2: Tensile strength and elongation at break after pre-conditioning - Wrapping test after thermal ageing in air - Measurement of mass increase - Long-term stability test - Test method for copper-catalysed oxidative degradation	EN 60811-4-2	1999
IEC 60811-5-1 (mod)	1990	Part 5-1: Methods specific to filling compounds - Drop point - Separation of oil - Lower temperature brittleness - Total acid number - Absence of corrosive components - Permittivity at 23 °C - D.C. resistivity at 23 °C and 100 °C	EN 60811-5-1	1999

[1)] EN 50183:2000, which is related to IEC 60104:1987, applies.

Publication	Year	Title	EN/HD	Year
IEC 60888	1987	Zinc-coated steel wires for stranded conductors	-	-
IEC 60889	1987	Hard-drawn aluminium wire for overhead line conductors	EN 60889	1997
IEC 61089 [2)]	1991	Round wire concentric lay overhead electrical stranded conductors	-	-
IEC 61232 (mod)	1993	Aluminium-clad steel wires for electrical purposes	EN 61232	1995
IEC 61394	1997	Overhead lines - Characteristics of greases for aluminium, aluminium alloy and steel bare conductors	-	-
IEC 61395	1998	Overhead electrical conductors - Creep test procedures for stranded conductors	EN 61395	1998

2) EN 50182:2001, which is related to IEC 61089:1991, applied.

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